京都大学	博士（工学）	氏名	SATTRAWUT PONBOON
論文題目	EXACT SOLUTIONS FOR LOCATION-ROUTING PROBLEMS WITH TIME WINDOWS USING BRANCH-AND-PRICE METHOD（分枝価格法を用いたタイムウィンドウ付配置配送計画の厳密解）		

(Summary of the thesis)

This study proposes a branch-and-price algorithm to solve the Location-Routing Problem with Time Windows (LRPTW) which has never been attempted with the exact solutions before. It consists of seven chapters that can be summarized as follows.

Chapter 1: Introduction

The first chapter describes the broad introduction about the situation of supply chain and logistics management systems. The cost components of transportation, warehousing, inventory, order processing, and administration are explored. The research motivation for location analysis is introduced. It leads to the purpose and objectives of this research, together with the lists of research contributions.

Chapter 2: Literature Review

Chapter 2 reviews the literature related to this research. Two types of location problems are described which are a location on a continuous plane and location on a network. The latter receives more interests in the field of network and transportation sciences. The integration between location and routing problems is comprehensively described with the exact solution methods. The details related to time windows and benchmark instances are also provided.

Chapter 3: Methodology

Chapter 3 presents the main formulation of LRPTW. The objective function and eleven constraints are described in details. The branch-and-price algorithm is as a main tool to solve LRPTW. It consists of a master problem and subproblem. The master problem considers only a subset of variables from the original while the subproblem identifies the new variables. The objective function of the subproblem considers the reduced cost of the new variables with respect to the current dual variables. The master problem uses a simplex algorithm, and the subproblem uses an Elementary Shortest Path Problem with Resource Constraints (ESPPRC) as the main tools. The accelerating processes and branching strategies are also described in details.

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Chapter 4: Model Evaluation

The results and effects of time windows on testing instances, developed from VRPTW Solomon benchmarks, are shown in Chapter 4. The original depot is replaced by the new three potential depot sites together with other parameters used in the LRPTW formulations. The results show the cost components including the depot, vehicle, distance, load, and computational time. It is proved that the new exact algorithm can solve the LRPTW instances to optimality within an acceptable time. Moreover, the exact solutions of the LRPTW can reduce the required number of vehicles as well as the distance traveled as compared to the exact VRPTW solutions.

Chapter 5: LRPTW in Osaka Distribution Network

The first application of LRPTW in Osaka distribution network is examined in this chapter. It evaluates the cost structure on different factors of LRPTW which is rarely observed by the exact algorithm. The main decision factors for LRPTW are the location of the depot, depot size, and vehicle size. It is found that the large size depot together with the large size vehicle is among the best scheme in our case study. The depot located in Minato-ku is the best location for the large size depot scenario by the fact that it is located in the low-price area.

Chapter 6: LRPTW in Ishinomaki Humanitarian Logistics

Another application is proposed for a humanitarian relief operations in Ishinomaki. The LRPTW tabu search is adapted to determine the location of refugee centers or depots to inventory food and important commodities for the victims. Apart from the two depot locations used in the real operation, we propose eight additional locations all over the city and determine the optimal locations in four different scenarios. The results are expected to provide the broader perspective on how mathematical models can support the humanitarian logistics in disaster relief operation.

Chapter 7: Conclusion and Recommendation

Finally, the conclusions of this research are summarized, and the further extensions to this research are also presented in Chapter 7.

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（論文審査の結果の要旨）

本論文は、都市内物流システムにおいて重要な役割を果たすタイムウィンドウ付物流拠点配置配送計画の最適解について、列生成法および分枝価格法を用いて厳密解を求める方法論について明らかにしている。タイムウィンドウ付物流拠点配置配送計画は、ＮＰ－困難な組み合わせ最適化問題であり、物流拠点数および顧客数が増加すると厳密解を求めることが難しくなり、近似解を求めることが多いが、本論文では厳密解を求めている点に新規性が認められる。本論文の概要は以下の４点にまとめられる。

（１） タイムウィンドウ付物流拠点配置配送計画について、物流拠点の施設建設・運用費用、配送車両の固定費用、総走行費用の総和を最小化するような混合整数計画問題として定式化を行った。

（２） タイムウィンドウ付物流拠点配置配送計画は、通常の物流拠点配置配送計画に比べて、顧客位置への配送車両の到着に時間制約があるため、より複雑な問題となっている。この複雑な問題の厳密解を求めるために列生成法に基づく分枝価格法およびラベリングアルゴリズムを新たに開発し、物流拠点数が 3、顧客数が ４０程度のタイムウィンドウ付物流拠点配置配送計画の厳密解を求めることに成功した。

（３） ここで開発したモデルを大阪の道路ネットワークにおける物流拠点配置配送計画に適用した。その結果、物流拠点数、車両台数、配送経路の最適解を求めることができ、物流拠点の規模、配送車両の積載量等の影響について評価できることを示した。

（４） さらに大規模なタイムウィンドウ付物流拠点配置配送計画の近似解を求めるためにタブーサーチを用いた方法を開発し、石巻の道路ネットワークにおける物流拠点配置配送計画に適用し、物流拠点の施設建設・運用費用の影響について明らかにした。

以上のように、本論文は効率的かつ環境に優しい都市内物流システムを構築するために重要な役割を果たすタイムウィンドウ付物流拠点配置配送計画について、厳密解を求める方法論を開発しており、学術面において大きな貢献を行っているとともに実際面においても寄与するところが少なくない。よって、本論文は博士（工学）の学位論文として価値あるものと認める。また、平成２７年７月 22 日、論文内容とそれに関連した事項について試問を行って、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。

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